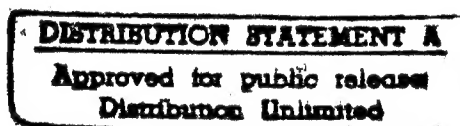


# ALTERNATE MATERIALS OF CONSTRUCTION FOR GEOTHERMAL APPLICATIONS

PROGRESS REPORT NO. 12  
JANUARY - MARCH 1977

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PROCESS TECHNOLOGY DIVISION  
DEPARTMENT OF APPLIED SCIENCE

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# **ALTERNATE MATERIALS OF CONSTRUCTION FOR GEOTHERMAL APPLICATIONS**

**PROGRESS REPORT NO. 12  
JANUARY - MARCH 1977**

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### Abstract

A program to determine if concrete polymer materials can be utilized as materials of construction in geothermal processes is in progress. To date, several high temperature polymer concrete systems have been formulated, laboratory and field tests performed in brine, flashing brine, and steam at temperatures up to 260°C (500°F), and economic studies started. Laboratory data for exposure times up to 2 years are available. Results are also available from field exposures of up to 12 months in four geothermal environments. Good durability is indicated. Work at two of these sites is continuing and tests have recently been initiated at two locations in the Imperial Valley. Work accomplished during the period January 1-March 31, 1977 is described in the current report.

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### Summary

Two new monomer formulations have been developed which may extend the operating limit for polymer concrete (PC) in brine to  $> 260^{\circ}\text{C}$  ( $500^{\circ}\text{F}$ ). The onset of decomposition of a polymer containing 50 wt % styrene - 32.8 wt % acrylonitrile - 9 wt % TMPTMA - 8.2 wt % polyphenylene oxide is  $262^{\circ}\text{C}$  ( $503^{\circ}\text{F}$ ). The use of 30 wt % styrene in conjunction with 60 wt % triallyl cyanurate and 10 wt % polyphenylene oxide produces a polymer that starts to decompose at  $286^{\circ}\text{C}$  ( $547^{\circ}\text{F}$ ).

A technique for producing PC-lined carbon steel pipe has been developed. A 6-in.-diam section of lined pipe has been sent to Raft River for testing. Sections of 2 and 3-in. pipe are being prepared for testing at East Mesa.

Laboratory testing of specimens in simulated geothermal environments was continued. Samples exposed to 25% brine at  $238^{\circ}\text{C}$  ( $460^{\circ}\text{F}$ ) for up to 234 days have not deteriorated. Similar observations were made after exposure at  $177^{\circ}\text{F}$  ( $350^{\circ}\text{F}$ ) for 631 days.

Samples exposed to a pH 1 hydrochloric acid solution at  $90^{\circ}\text{C}$  ( $194^{\circ}\text{F}$ ) have not deteriorated. After 25 days in the solution at  $200^{\circ}\text{C}$  ( $392^{\circ}\text{F}$ ), PC containing a silica sand-portland cement aggregate is unaffected. Cracking has occurred with samples containing limestone aggregate.

Evaluation of samples exposed at Klamath Falls for one year has been completed. The results from compressive strength measurements indicate no significant reductions in strength. This concludes the current test program at Klamath Falls.

Testing of specimens at Raft River and The Geysers is continuing. Specimens will be removed for examination during the next quarter.

Field tests utilizing the Battelle Northwest Laboratory equipment at East Mesa were started during March. The test consists of the exposure of

48 specimens of PC to 160°C (320°F) brine flowing from Well 6-1. Examination of the samples will be made after exposure for 70 days.

Samples have also been installed at six locations in the Bureau of Mines test facility in the Imperial Valley. The test is scheduled to start during April.

The applicability of polymer concrete as an electrical insulator has been demonstrated by EPRI-sponsored research. This work will have application in the transmission of power from geothermal plants. The mechanical strength of polymer concrete is equivalent to that of porcelain but it has twice the dielectric strength. It can also be used for configurations too complex for porcelain materials. The estimated cost of a polymer concrete insulator is less than half of the cost of porcelain.

Alternate Materials of Construction  
for Geothermal Applications

Progress Report No. 12  
January-March 1977

Introduction

Concrete polymer materials are a series of composite materials which have strength and durability characteristics far superior to those of portland cement concrete. As a result, two of these materials, polymer impregnated concrete and polymer concrete, are beginning to be utilized throughout the world in applications where portland cement concrete cannot be used or where severe maintenance problems occur. Recent results from laboratory and field tests indicate that the composites may be applicable to many parts of geothermal processes.

Polymer impregnated concrete (PIC) consists of a precast portland cement concrete impregnated with a monomer system that is subsequently polymerized in situ. The polymer tends to fill the porous void volume of the concrete, which results in significant improvements in strength and durability properties. For a concrete mix that produces specimens with a compressive strength of 5,000 psi, compressive strengths > 20,000 psi have been measured after impregnation. Similarly large improvements in other structural and durability properties have also been obtained.

Polymer concrete (PC) consists of an aggregate mixed with a monomer or resin that is subsequently polymerized in place. The techniques used for mixing and placement are similar to those used for portland cement concrete. After curing, a high strength (> 10,000 psi), durable material is produced.

A third type of material, a further development of PIC, is also being applied. This is a precast concrete that has been partially impregnated to a finite depth with a monomer that is subsequently polymerized.

The feasibility of using concrete polymer composites as materials of construction for handling hot brine and steam was demonstrated in 1972.<sup>1</sup> As part of this work the concrete liner on a vertical tube evaporator at the Office of Saline Water Desalting Facility in Freeport, Texas was partially impregnated to a depth of  $\sim 0.25$  in. The results from these tests indicated that the composites had long-term stability in seawater at 177°C (350°F) and in acid solutions. Based upon these results, a research program to develop the composites for use in geothermal systems was started in April 1974. To date, high temperature PC systems have been formulated, and laboratory and field tests performed in brine, flashing brine, and steam at temperatures up to 238°C (460°F). Results are available from field exposures of up to 12 months in four geothermal environments. Good durability is indicated. Recently, tests at two other sites have been started. The results from these studies are summarized below.

#### Summary of Earlier Work

Work to develop high temperature PC formulations was continuing. Two monomer formulations, 60 wt % styrene - 40 wt % trimethylolpropane trimethacrylate (TMPTMA) and 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA showed promise after long-term testing. Both systems can be polymerized using chemical initiators and heat or by chemical initiators and promoters.



The durability of PC to hot brine and steam has been found to be highly dependent upon the composition of the aggregate. For use at temperatures  $< 218^{\circ}\text{C}$  ( $425^{\circ}\text{F}$ ), aggregate materials such as quartz, silica, flyash, and sand can be used. Above  $218^{\circ}\text{C}$  ( $425^{\circ}\text{F}$ ), only PC materials containing aggregate consisting of silica sand-portland cement mixtures have been durable.

Laboratory testing of specimens in simulated geothermal environments was in progress. Samples have been examined after exposure to 25% brine at  $177^{\circ}\text{C}$  ( $350^{\circ}\text{F}$ ) for 601 days, 25% brine at  $238^{\circ}\text{C}$  ( $460^{\circ}\text{F}$ ) for  $\sim 200$  days, and 400 ppm brine at  $150^{\circ}\text{C}$  ( $302^{\circ}\text{F}$ ) for 247 days. Good durability was indicated. PC exposed to pH 1 hydrochloric acid at  $90^{\circ}\text{C}$  ( $194^{\circ}\text{F}$ ) for 110 days had not deteriorated. The concrete control failed after 21 days.

Initial field tests at Baca Wells, The Geysers, Raft River, and Klamath Falls were completed. Second series are in progress at The Geysers and Raft River. After exposures of up to 1 year, no serious deterioration was apparent.

Economic studies to identify potential applications for concrete polymer materials in geothermal processes have been started. Applications in condensate piping systems, acid handling systems, reinjection lines, cooling towers, district heating systems, and to repair and protect concrete surfaces appear cost effective.

During the second quarter of FY 1977, work was continued in each of the program tasks. This work is described in the current report.

#### Task 1 Selection of Lining Materials

Work is being performed to develop polymer formulations and PC composites which can be used as materials of construction at temperatures

up to 260°C (500°F). Research is also being performed to determine if materials can be formulated for use as well cementing materials at temperatures up to 400°C (750°F). This work is described in a separate program entitled "Cementing of Geothermal Wells".<sup>2</sup>

During the current report period the decomposition temperatures of several polymers were measured. These results are summarized in Table 1. Two systems appear promising but only limited testing has been performed. The onset of decomposition of polymer containing 50 wt % styrene - 32.8 wt % acrylonitrile - 9 wt % TMPTMA - 8.2 wt % polyphenylene oxide is 262°C (504°F). The use of 30 wt % styrene in conjunction with 60 wt % triallyl cyanurate and 10 wt % polyphenylene oxide produces a polymer that starts to decompose at 286°C (547°F). Experiments to measure the strength and permeability of these systems after long-term exposure to hot brine have been started but test data are not yet available.

Experiments with several other monomer mixtures were also performed. These systems are as follows: styrene-acrylonitrile-acrylamide, styrene-acrylonitrile-methacrylamide, isobornyl methacrylate-methyl methacrylate, isobornyl methacrylate-methyl methacrylate-ethylthioethyl methacrylate, and isobornyl methacrylate-methyl methacrylate-acrylonitrile.

PC specimens consisting of 12 wt % of the monomers and 88 wt % of a sand-portland cement aggregate mixture were exposed in an oven at 238°C (460°F) for 30 days and to 25% brine at 260°C (500°F) for 10 days. Based upon the results from compressive strength and water absorption measurements, two formulations, 55 wt % styrene - 40 wt % acrylonitrile - 5 wt % acrylamide and 55 wt % styrene - 37.5 wt % acrylonitrile - 7.5 wt % methacrylamide, were selected for additional evaluation. Long-term testing has been started.

Table 1

## Decomposition Temperatures of Polymer Formulations

<u>Polymer</u>	<u>Decomposition temperature, °C</u>	
	<u>onset</u>	<u>end</u>
80% S - 12% PPO - 8% TMPTMA	232	457
85% S - 7% PPO - 8% TMPTMA	218	443
90% S - 2% PPO - 8% TMPTMA	209	436
78% S - 12% PPO - 10% TMPTMA	209	445
68% S - 12% PPO - 20% TMPTMA	233	435
58% S - 12% PPO - 30% TMPTMA	235	< 500
70% Derakane - 30% TAC	193	< 500
50% Derakane - 50% TAC	137	460
40% Derakane - 60% TAC	101	456
TAC	112	276
60% S - 40% TMPTMA	150	426
55% S - 36% ACN - 9% TMPTMA	221	427
50% S - 32.8% ACN - 9% TMPTMA - 8.2% PPO	262	426
30% S - 60% TAC - 10% PPO	286	460
20% S - 70% TAC - 10% PPO	240	459

Heating rate, 20°C/min

S, styrene

PPO, polyphenylene oxide

TMPTMA, trimethylolpropane trimethacrylate

TAC, triallyl cyanurate

ACN, acrylonitrile

Differential thermal analysis (DTA) studies have been initiated during the current report period to determine why the addition of portland cement to silica sand aggregate results in improved durability. In these tests, each of the chemical constituents of Type III portland cement ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{CaO}$ , and  $\text{MgO}$ ) are being combined with silica sand in a PC formulation consisting of 12 wt % monomer (55 wt % styrene - 36 wt % acrylonitrile - 9 wt % TMPTMA) and 88 wt % aggregate (80 wt % sand - 20 wt % portland cement constituent). DTA measurements are being performed before and after exposure in an oven to high temperature and to hot brine.

A proprietary polymer cement material produced by Versar, Inc. of Springfield, Virginia has been received for evaluation. The PC consists of a dense carbon filler and an acid catalyzed furane resin binder. The material is cured at  $200^\circ\text{C}$  ( $392^\circ\text{F}$ ) and it is claimed will withstand temperatures up to  $375^\circ\text{C}$  ( $707^\circ\text{F}$ ). The stability of the material after exposure to hot brine will be determined.

Samples of the carbon filler have been requested. It is planned to use the material in conjunction with several BNL-developed polymers which appear to have better high temperature properties than furane resins.

## Task 2 Process Technology

Work is in progress to develop the technology required to produce PC or PC-lined carbon steel pipe and vessels for use in containing geothermal fluids. It is planned to field test prototypes at Raft River, East Mesa, and possibly Boise.

During the previous report period sections of PC pipe were fabricated for use in long-term ( $\sim 30$  day) hydrostatic tests at elevated temperature.

Test conditions were 200 psi at 150°C (302°F). In the initial tests, the ends of the pipe were sealed with steel plates which were bolted together using connecting rods. This was unsuccessful since heating of the restrained configuration caused the pipe to crack, probably due to the difference between the thermal expansion of the PC and the steel rods. Sealing problems occurred when it was attempted to heat the configuration prior to tightening the connecting rods.

The above problems were resolved by casting 4-in. Sch 40 flanged steel pipe into the ends of the PC pipe, thereby allowing the pipe to expand freely. This technique has eliminated the cracking and sealing problems and appears to be a suitable method for joining PC pipe to steel components. Hydrostatic testing of pipe at the anticipated conditions at Raft River is now in progress.

A 4-ft section of PC-lined pipe has been fabricated and shipped to Raft River for testing. The section, shown in Figure 1, consists of a 6-in.-diam Sch 40 carbon steel pipe with concentric reducers to 4-in. Sch 40 pipe. A 1-in.-thick PC liner consisting of a monomer mixture of 70 wt % Derakane-30 wt % triallyl cyanurate and an 80 wt % silica sand-20 wt % calcium lumnite cement aggregate was applied to the wall of the 6-in. pipe. This monomer system was selected based upon the decomposition temperature of 193°C (379°F) and the relatively high viscosity which is advantageous in producing thin liners. The inner surface of the pipe is shown in Figure 2.

In preparation for tests to be performed at East Mesa, 3/8-in. PC liners have been placed on pieces of 2 and 3-in. Sch 40 pipe. Contingent upon the results from this work, up to 8-ft long pieces will be prepared and shipped to the field test site (see Task 4).



Figure 1. PC-lined carbon steel pipe prior to shipping to Raft River for field testing.



Figure 2. Inner surface of carbon steel pipe lined with PC containing 70 wt % Derakane - 30 wt % tri-allyl cyanurate.

### Task 3 Physical and Chemical Property Measurements

In support of the experimental work being performed in Tasks 1, 2, and 4, the mechanical and chemical resistance properties of concrete polymer materials are being determined. The tests are being performed in autoclaves at conditions simulating environments in which field tests are in progress or being planned. The facility consists of 10 autoclaves which are designed for continuous operation with brine and steam at a temperature of 220°C (428°F) and two other pressure vessels rated at 280°C (536°F).

Preliminary testing of PC specimens in an autoclave containing a 25% concentration of synthetic Imperial Valley geothermal brine at a temperature of 177°C (350°F) was continued during the report period. The temperature condition for this test is approximately the same as that expected at the inlet to the second steam separator at the San Diego Gas and Electric Company (SDG & E) facility when the well-head temperature is at 238°C (460°F), and is ~ 80°C (144°F) higher than the temperature at which specimens were exposed at Baca Wells.

Two PC formulations, 60 wt % styrene - 40 wt % TMPTMA and 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA are being evaluated. The formulations consist of 12 wt % of the monomer mixture and 88 wt % of a 90 wt % silica sand - 10 wt % portland cement aggregate. Polymerization was initiated using 2% benzoyl peroxide by weight of monomer and heating to 80°C (176°F).

The results of compressive strength measurements made on the specimens as a function of time are given in Table 2. As noted, both series exhibited initial reductions in strength, probably due to the decomposition of low



Table 2

Compressive Strength of PC After Exposure  
to 25% Brine at 177°C

<u>Monomer system</u>	<u>PC No. 1</u>	<u>PC No. 2</u>
<u>Exposure time, days</u>	<u>Compressive strength, psi</u>	
0	9600	10900
63	4450	7000
142	3900	6100
280	4352	7567
466	4355	7511

PC No. 1, 60 wt % styrene - 40 wt % TMPTMA.

PC No. 2, 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA.

Aggregate, 90 wt % sand - 10 wt % portland cement.

Specimen size, 0.75-in.-diam x 1.5-in.-long.

Strengths measured at 20°C.

molecular weight fractions of the polymer. Similar trends have been noted for most of the systems evaluated to date. Strengths measured after exposure for 466 days were essentially the same as those measured after 63 days. Visual inspection after 631 days has indicated no cracking or other signs of deterioration. This test is continuing.

Tests in an environment simulating the anticipated well-head conditions at the San Diego Gas and Electric Co. facility (25% brine, 238°C (460°F)) are continuing. Two PC formulations have now been in test for 210 days and another for 234 days. A description of the specimens was given in the previous report. All of the samples remain crack-free, dimensionally stable, and have not exhibited weight losses. This test is continuing.

Three additional sets of specimens have been placed in test at the above conditions. After exposure for 31 days, no deterioration is apparent. During the next report period one sample from each set will be tested in compression.

The testing of a 3.5-in.-i.d. x 1-in.-wall PC pipe which is a prototype of sections to be installed at Raft River was continued. No evidence of attack is apparent after exposure for 176 days to the 400 ppm brine solution at 150°C (302°F). This test is being continued.

A serious problem associated with the conversion of the energy content of hypersaline geothermal systems to electric power is precipitation of amorphous silica and other phases that can ultimately cause scaling of the power plant equipment. The rate of polymerization of monomeric silica is dependent upon pH, temperature, salinity, silica concentration, and the presence of solids. Recent work at Lawrence Livermore Laboratory<sup>3</sup> has indicated that a reduction of pH levels over the range 5.0 to 1.6

resulted in complete elimination of scale over the temperature range 220°C (428°F) to 105°C (221°F).

Tests are in progress to determine the feasibility of using concrete polymer materials in high temperature-low pH environments. Two tests are being performed.

Three samples of PC were exposed to a pH 3 hydrochloric acid solution at 20°C (68°F) for 300 days. No evidence of attack on the PC was apparent and the concrete control exhibited only a small weight loss. The temperature was then raised to 90°C (194°F). Evidence of attack on the concrete control was immediate and after 40 days a 21% weight loss was measured. The PC weight remained constant.

The three PC samples were then exposed to a pH 1 hydrochloric acid solution at 90°C (194°F). After 21 days, the concrete control had a weight loss of 19%. No evidence of corrosion of the PC as determined by weight change and pH measurements has been detected after exposure for 236 days. These samples are shown in Figure 3. The test is continuing.

A test in pH 1 hydrochloric acid at 200°C (392°F) has recently been started. Three monomer systems, 60 wt % styrene - 40 wt % TMPTMA, 60 wt % styrene - 40 wt % TMPTMA to which 10% Hetron was added, and 55 wt % styrene - 36 wt % acrylonitrile - 9 wt % TMPTMA, are being tested. The latter was used in a PC formulation containing 90 wt % silica sand - 10 wt % portland cement aggregate. Limestone was used as the aggregate with the styrene-TMPTMA system. To date, after 25 days in test, the sample containing the sand-cement aggregate has not deteriorated. The samples containing limestone have cracked (see Figure 4). This test is continuing.

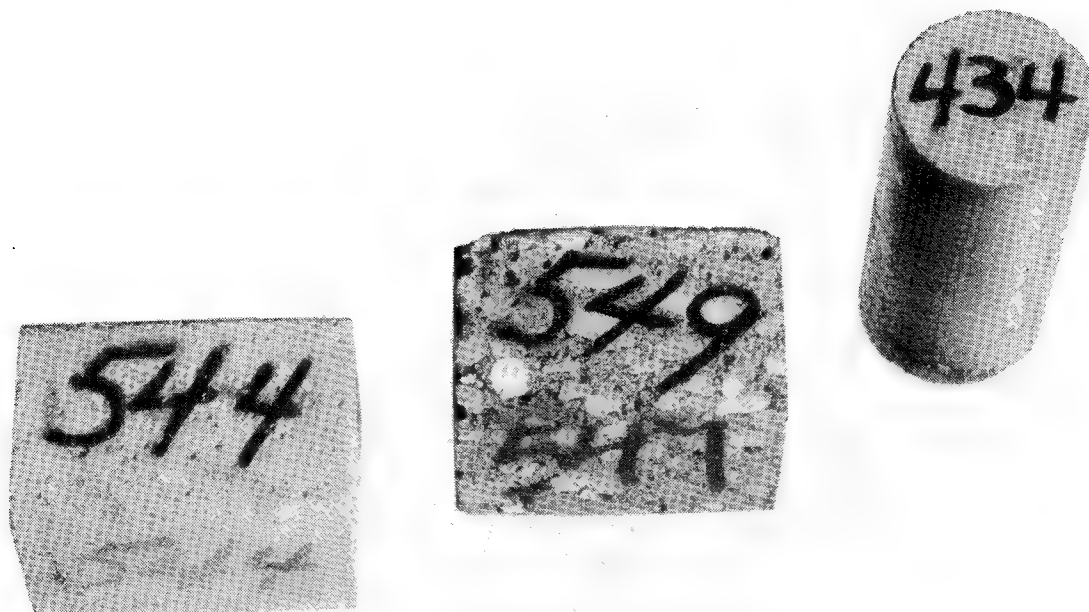


Figure 3. PC after exposure to pH 1 hydrochloric acid at 90°C for 236 days. Concrete control failed after 21 days.

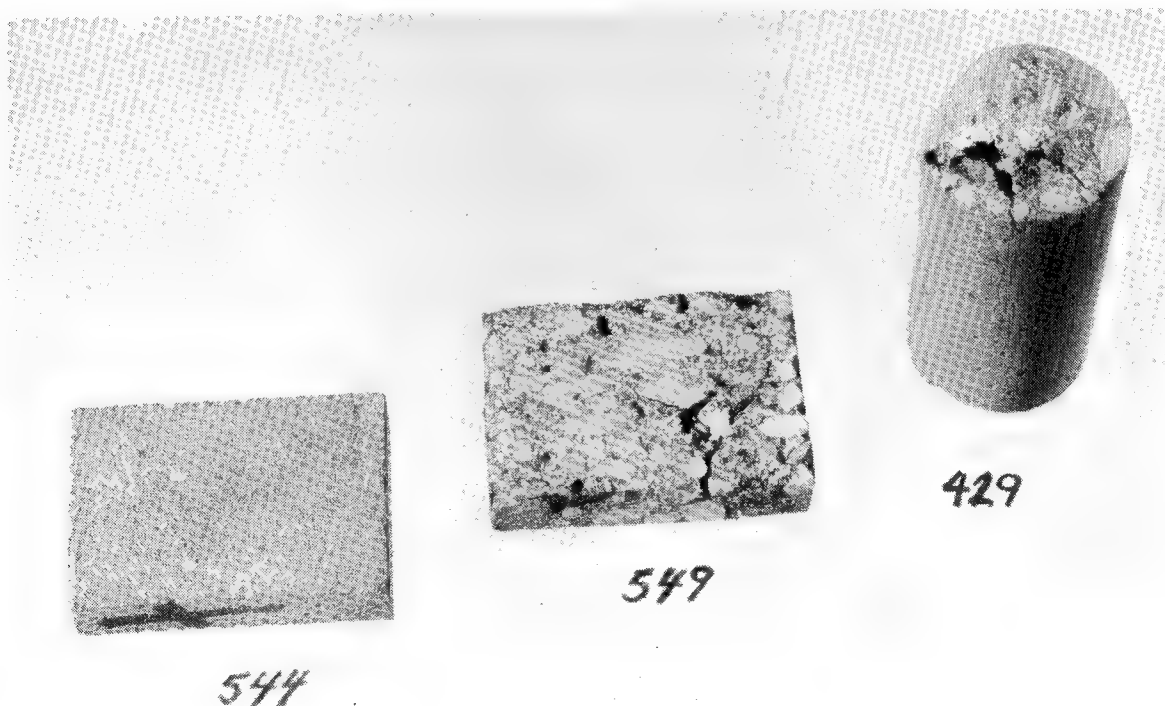


Figure 4. PC after exposure to pH 1 hydrochloric acid at 200°C for 25 days. Sample 544 contains silica sand-portland cement aggregate. Others contain limestone.

#### Task 4 Field Tests

To date, test series have been completed at The Geysers,, Baca Wells, Klamath Falls, and Raft River. Second test series are in progress at The Geysers and Raft River. During the current report period tests were initiated at East Mesa and Calipatria. The status of each of these programs is summarized below.

##### The Geysers

Tests are in progress to determine the durability of PC when exposed in a well-head chamber to dry steam at 238°C (460°F). A preliminary test series was completed in September 1975 which indicated that the materials had high strength and low permeability after exposure for 90 days.<sup>4</sup>

Based upon these data, a second series of samples was placed in test during November 1975. Two monomer systems, 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA and 55 wt % styrene - 36 wt % acrylonitrile - 9 wt % TMPTMA, are being tested. Aggregate composition and polymerization method are other variables in the test series.

Samples have been evaluated after exposure for 90, 180, and 365 days. All samples containing an aggregate consisting of 90 wt % silica sand - 10 wt % portland cement have shown good durability. Composites containing other aggregates failed. The average compressive strength of specimens exposed to the test conditions for 1 year was 4200 psi, ~ 50% of the control but in fair agreement with a value of 4900 psi that was measured after a 90 day exposure. This test is continuing. The next evaluation is scheduled after exposure for 18 months (May 1977).

##### Baca Wells

A test to determine the durability of PC to flashing brine at a temperature of ~ 160°C (320°F) was performed at Baca Wells, New Mexico. The total exposure time was 180 days.

The test series consisted of two monomer mixtures, 60 wt % styrene - 40 wt % TMPTMA and 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA, mixed with an aggregate consisting of 90 wt % silica sand and 10 wt % portland cement. Three different polymerization methods were utilized.

The specimens were found to be in good condition after the 180 day test. Two samples which contained the 60 wt % styrene - 40 wt % TMPTMA mixture polymerized using benzoyl peroxide and dimethyl aniline, were slightly cracked. All of the other materials were crack free.

Tests performed on the samples included dimensional stability, weight change, water absorption, and compressive strength. Little if any changes in the dimensions and weight were detected. Compared to the controls, all of the samples containing styrene-TMPTMA had strengths which were essentially unaffected by the exposure. The samples containing styrene-acrylonitrile-TMPTMA polymerized by promoters and initiators were also unaffected. The other samples exhibited slight strength reductions and increases in absorption. These strengths were in the same order as those obtained after 180 day exposures at The Geysers (~ 4500 psi).

#### Klamath Falls

Samples of concrete polymer materials have been exposed to low temperature geothermal fluids at Klamath Falls, Oregon.

Field testing was started in November 1975. Forty-eight cylindrical specimens of PC, PIC, and glass polymer composite (GPC) were placed into wells at temperatures ranging between 27°C and 99°C (81° and 210°F). The final set of specimens in the series was removed from the wells in November 1976 after exposure for 365 days. These samples are shown in Figure 5. Earlier evaluations were performed after 90 and 180 day exposures.<sup>5</sup> The evaluation



Figure 5. Samples after exposure for 1 year at Klamath Falls. Samples 424, 425, 432, 433, PC; 440, 441, GPC; 482, 483 PIC.

of all samples has been completed. The results from compressive strength and water absorption tests indicate that both properties are independent of the exposure temperature. The water absorptions remained constant throughout the test. Reductions in compression strength ranging between 14 to 18% were noted for samples exposed for 180 days. Beyond that time, the strengths remained essentially constant.

#### Raft River

Concrete polymer materials may have application in medium temperature geothermal systems where piping with low-cost, minimum thermal losses, and durability to internal and external environmental conditions is essential. Geothermal fluids meeting this condition (temperature  $\sim 150^{\circ}\text{C}$  ( $302^{\circ}\text{F}$ )) exist in the Raft River Valley Region of Idaho where testing of concrete polymer materials has been started. To date, one test series has been completed and a second is in progress.

In the first experiment, twenty 2-in.-diam x 0.25-in.-thick cement discs, impregnated with 60 wt % styrene - 40 wt % TMPTMA, were subjected to the fluid in an attempt to measure the resistance of PIC to abrasion. After 70 days in test, no deterioration of the PIC was apparent. Severe attack was noted on several metallic samples.

Testing of PC samples in the "Raft River Mobile Corrosion, Deposition, and Component Test Laboratory" (see Figure 6) was started in September 1976. The test conditions are as follows: temperature  $135^{\circ}\text{C}$  ( $275^{\circ}\text{F}$ ), flow 200 gpm, and pressure 130 psi. To date only the results from samples exposed for 90 days are available. These data indicate trends similar to those obtained in the other field tests; slight reductions in strength, dimensional stability, and constant water absorption. This test is continuing. The next inspection



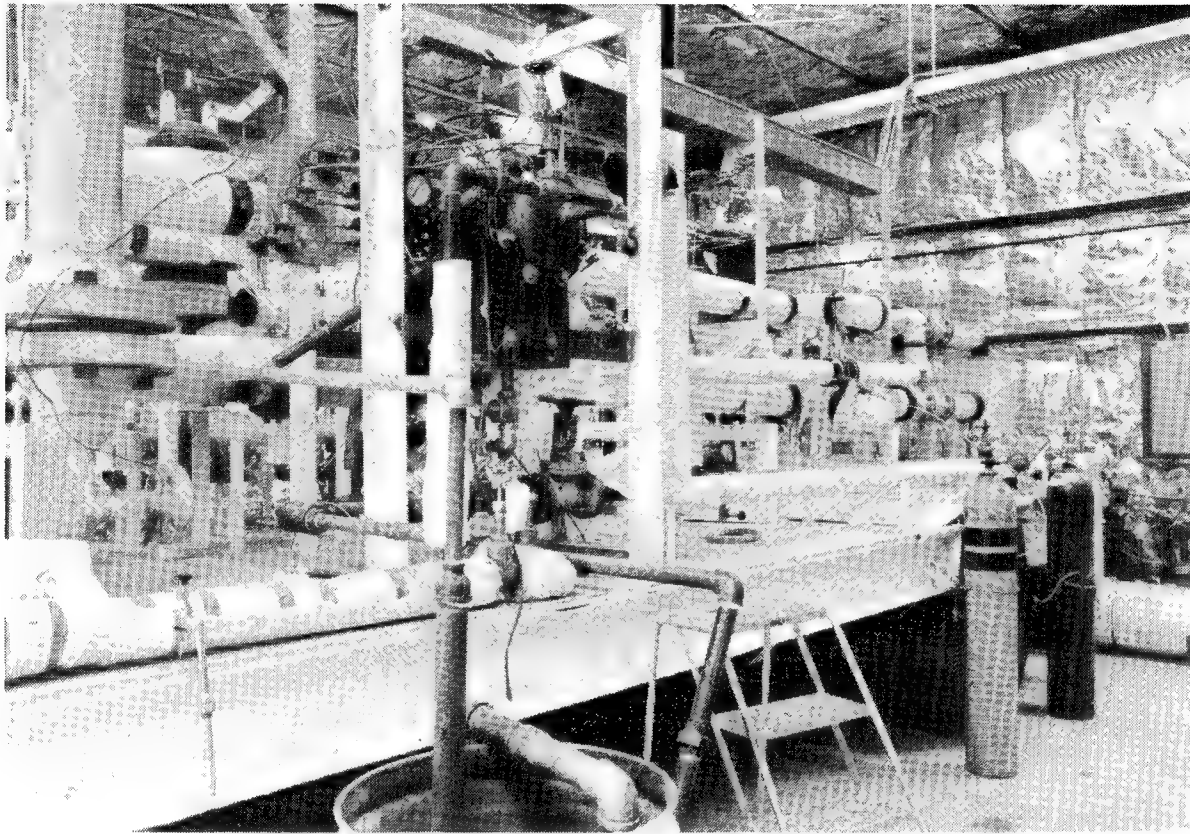


Figure 6. Raft River facility in which PC specimens are being tested.

of specimens will take place during the next report period.

During the current report period a section of PC-lined pipe was shipped to the test site for installation. A description of the section was given in Task 2. To date, the test has not been started.

#### East Mesa

With the cooperation of the Battelle Northwest Laboratory (BNWL), a test was initiated in the Imperial Valley at East Mesa during March. In this work, 48 hollow cylinders of PC (7/8-in.-o.d. x 3/16-in. wall x 2 3/8-in.-long are being exposed to flowing brine at  $\sim 160^{\circ}\text{C}$  ( $320^{\circ}\text{F}$ ). The samples, which simulate PC pipe, are installed in an 8-ft section of 2-in.-Sch 40 pipe which serves as a by-pass around the BNWL test configuration. Two monomer mixtures, 50 wt % styrene - 33 wt % acrylonitrile - 17 wt % TMPTMA and 55 wt % styrene - 36 wt % acrylonitrile - 9 wt % TMPTMA, are being evaluated in conjunction with aggregate containing 4/1 and 1/1 ratios of sand and portland cement. Typical specimens are shown in Figure 7. The location of the specimens in the BNWL facility is shown in Figure 8. The first examination of specimens will be made after a 70 day exposure.

Plans are being made to install up to 8-ft sections of PC-lined pipe in the facility. PC overlays as a means of protecting concrete mounting pads from deterioration by brine and acids will also be evaluated at East Mesa.

#### Calipatria/Niland

A total of 24 PC samples (1 3/16-in.-diam x 2 3/8-in.-long) were installed in the Bureau of Mines (USBM) facility in the Calipatria/Niland area of the Imperial Valley (see Figure 9). The test is presently scheduled to start during April. One monomer mixture, 55 wt % styrene - 36 wt % acrylonitrile - 9 wt % TMPTMA, and two sand-portland cement aggregate mixtures, 9/1 and 4/1,

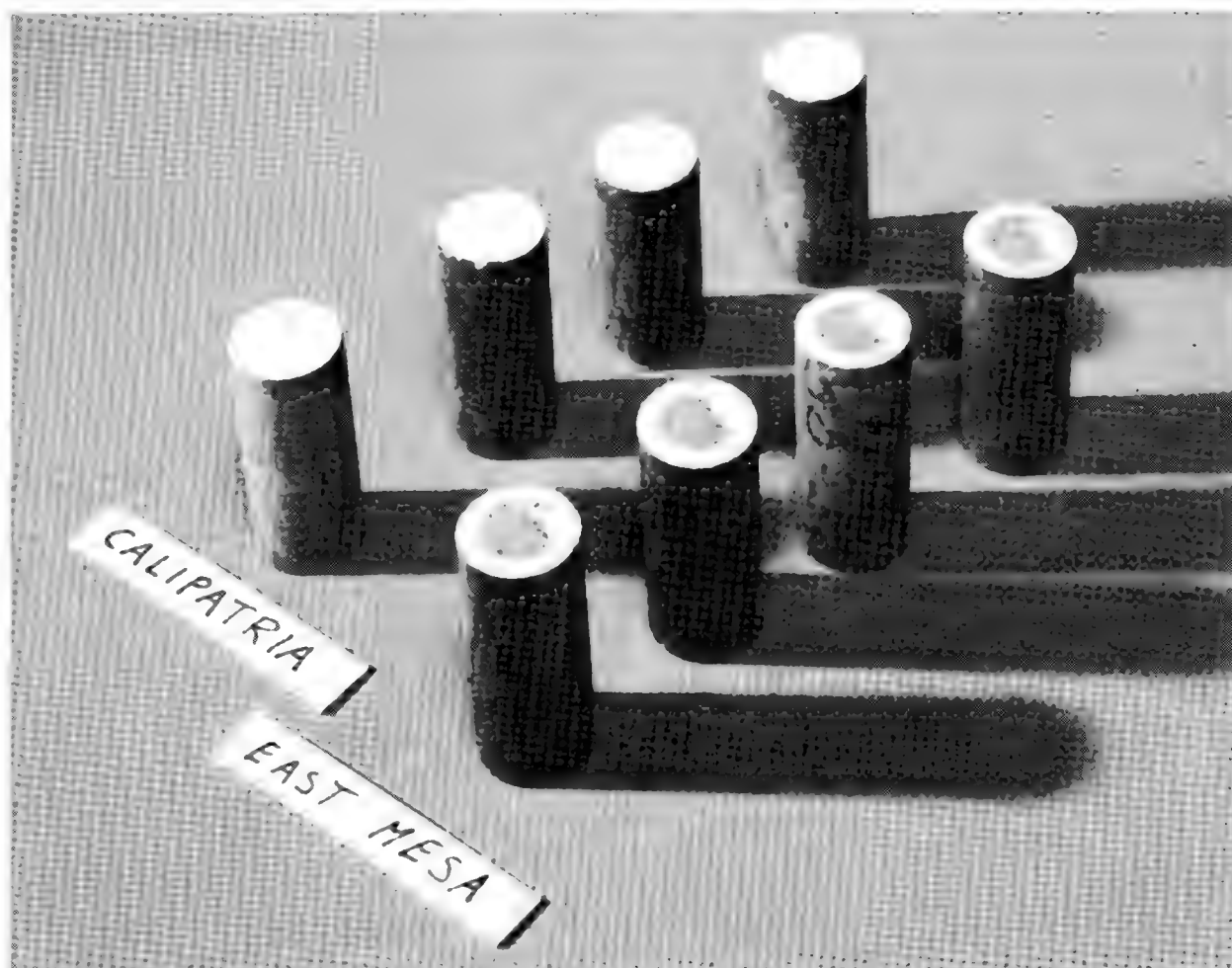


Figure 7. PC specimens of the type being exposed to hot flowing brine in the Imperial Valley.

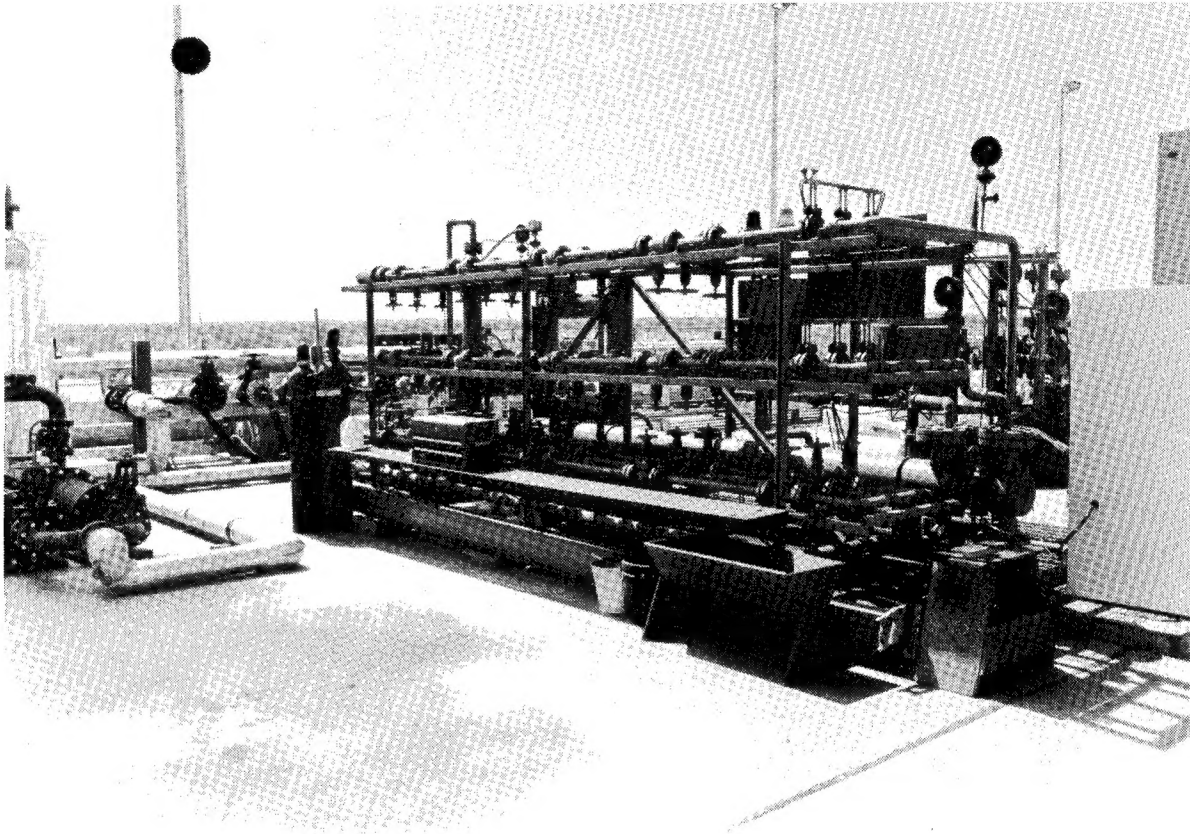


Figure 8. BNWL test facility at East Mesa. The PC specimens are positioned in the insulated pipe in the left foreground of the figure.

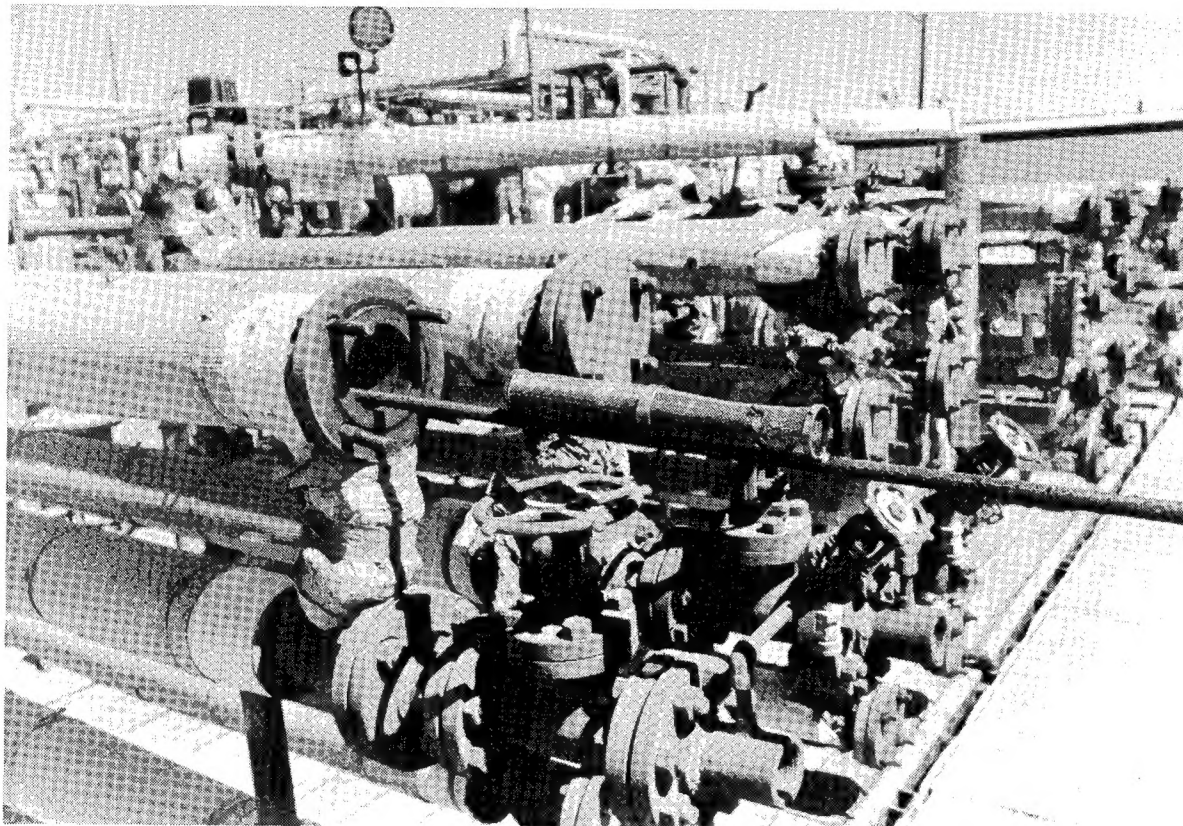


Figure 9. Sample basket being inserted into test facility at the Calipatria/Niland site in the Imperial Valley.

will be exposed to six environments. These are in the 220°C (428°F) brine at the inlet to the first steam separator, the brine and steam effluents from the first steam separator, the brine and steam effluents from the second steam separator, and at the steam/brine interface in the second separator. Typical specimens were shown in Figure 7.

#### Task 5 Technology Transfer and Economic Evaluation

The applicability of polymer concrete as an electrical insulator has been demonstrated by EPRI-sponsored research. This work will have application in the transmission of power from geothermal plants. The mechanical strength of polymer concrete is equivalent to that of porcelain but it has twice the dielectric strength. It can also be used for configurations too complex for porcelain materials. The estimated cost of a polymer concrete insulator is less than half of the cost of porcelain.<sup>6</sup>

#### Task 6 Administrative

During the current report period, three "Monthly Administrative Letters" were submitted to DGE and Quarterly Progress Report No. 11 was issued. A paper entitled "The Applicability of Concrete Polymer Materials for Use in Geothermal Environments" was prepared and accepted for presentation at the 1977 Society of Petroleum Engineers of AIME Symposium on Oilfield and Geothermal Chemistry.

## References

1. DePuy, G. W., and Kukacka, L. E., Editors, Concrete Polymer Materials, Fifth Topical Report, BNL 50390 and REC-ERC-73-12, Dec. 1973.
2. Cementing of Geothermal Wells, Progress Report No. 3, Oct.-Dec. 1976, BNL 50621.
3. LLL Geothermal Energy Development Program, Highlight Report for the Advanced Technology Development Program, ATHS-2, Lawrence Livermore Laboratory, September 3, 1976.
4. Concrete Polymer Materials for Geothermal Applications, Progress Report No. 7, Oct.-Dec. 1975, BNL 20865.
5. Alternate Materials of Construction for Geothermal Applications, Progress Report No. 10, July-September 1976, BNL 50594.
6. Electric Power Research Institute Journal, Jan./Feb. 1977, pp. 38-9.

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